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A note on the lower limit of the top quark production rate at the Tevatron

E. LAENEN[1]

Fermi National Accelerator Laboratory,
P.O. Box 500, MS 106
Batavia, Illinois 60510

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Abstract

In this note I list the results for two proposals for the estimate of the lower limit of the top quark production cross section as a function of the top quark mass. Recent parton distribution functions have been used, together with a conservative value of α_S.

[1]email: eric@fnth010.fnal.gov

At the Tevatron, the top quark will be mainly produced through $t\bar{t}$ pair creation. Both top quarks will then decay to a (W, b) pair, upon which each W can decay either hadronically or leptonically. It is in the channel where both W's decays leptonically, one to a (e, ν_e) pair, the other to a (μ, ν_μ) pair, that, due to fairly low backgrounds in this channel, most of the current search effort is concentrated. Using the known branching fractions of the above decays an experimental total cross section is determined, which is then compared with a curve of the theoretical cross section as a function of the top quark mass m, either to determine m, or establish a lower limit on it. At present the top quark still has not been discovered at the Tevatron, and thus a lower limit estimate of the theoretical cross section is needed to determine a lower limit on its mass. In this brief note I will merely present the results of two proposals for such a cross section.

The first proposal is based on an exact NLO calculation [1] and was made in [2]. There, the total NLO cross section was evaluated for three different values of the mass factorization (= renormalization) scale μ, viz. $\mu = 2m, m$, and $m/2$, and for various choices of $\alpha_S(\mu)$ and parton distribution functions. For the lower limit estimate the value giving the lowest cross section, $\mu = 2m$, was recommended, together with a conservative value of α_S, and a set of parton distibution functions which agree best with the most recent data. I have merely updated the proposal in [2] by using more recent parton distibution functions, and accompanying α_S. The results for this proposal are given in Table 1. Comparing with the numbers for the lower limit estimate in [2], one does not find a large difference. See [2] for more details.

The second proposal is based on [3]. It was shown there that higher order QCD corrections to the total cross section beyond NLO are large, and cannot be neglected. This is due to large logarithms coming from initial state soft gluon radiation, which dominate the QCD corrections to the $t\bar{t}$ cross section at the Tevatron at any order. In [3] these large logarithmic corrections were resummed to all orders. Unfortunately, it was found that the resummed all order cross section displays a strong sensitivity to non-perturbative (higher twist) effects. As a consequence, a determination of the top quark mass using the e, μ channel would be very imprecise [2] [4]. However, a lower estimate can

[2]This large uncertainty was used in [6] as an argument to advocate a search in the $W + 4$ jet channel.

be established which does not suffer from this uncertainty. Let us define

$$\sigma^{improved} = \sigma^{(0)} + \sigma^{(1)}_{\rm exact} + \sum_{i=2}^{\infty} \sigma^{(i)}_{\rm approx}, \tag{1}$$

where the i'th term stands for the $O(\alpha_S^i)$ correction to the cross section, and the 'approx' consists of taking only the leading and next-to-leading threshold-logarithmic corrections, which dominate the cross section at any given order. Since $\sigma^{(i)}_{\rm approx} > 0$ for all i at $\mu = m$ [3], the true total cross section is likely larger than

$$\sigma^{(0)} + \sigma^{(1)}_{\rm exact} + \sigma^{(2)}_{\rm approx}. \tag{2}$$

An explicit expression for $\sigma^{(2)}_{\rm approx}$ is given in [3]. The results are given in Table 1. They correspond to a larger lower limit estimate for a given top mass than those of the first proposal.

For both proposals I used the parton distribution function set MRS D-', and for α_S the two-loop expression

$$\alpha_S(\mu^2) = \frac{b_1}{\ln(\mu^2/\Lambda^2)}\left(1 - \frac{b_1^2}{b_2}\frac{\ln\ln(\mu^2/\Lambda^2)}{\ln(\mu^2/\Lambda^2)}\right), \tag{3}$$

with the conservative value $\Lambda^{(2,5)} = 0.105$ GeV. Here $b_1 = 12\pi/(33 - 2n_f)$ and $b_2 = 24\pi^2/(153 - 19n_f)$, with $n_f = 5$.

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Table 1.

m_{top}	σ [pb] First prop.	σ [pb] Second prop	m_{top}	σ [pb] First prop.	σ [pb] Second prop.
90	111	148	146	9.91	12.1
92	99.5	132	148	9.25	11.3
94	89.5	118	150	8.61	10.5
96	80.8	106	152	8.04	9.79
98	73.0	95.2	154	7.52	9.14
100	66.1	86.3	156	7.02	8.52
102	59.9	77.8	158	6.56	7.94
104	54.4	70.6	160	6.13	7.41
106	49.6	64.0	162	5.74	6.92
108	45.2	58.1	164	5.38	6.48
110	41.3	52.7	166	5.04	6.07
112	37.7	48.2	168	4.72	5.68
114	34.6	43.9	170	4.43	5.32
116	31.7	40.2	172	4.15	4.98
118	29.1	36.8	174	3.89	4.67
120	26.8	33.7	176	3.66	4.38
122	24.7	31.1	178	3.44	4.11
124	22.7	28.4	180	3.23	3.86
126	21.0	26.2	182	3.04	3.63
128	19.4	24.2	184	2.85	3.40
130	17.9	22.3	186	2.68	3.20
132	16.6	20.6	188	2.52	3.00
134	15.4	19.1	190	2.38	2.83
136	14.3	17.6	192	2.24	2.67
138	13.2	16.3	194	2.11	2.50
140	12.3	15.1	196	1.96	2.36
142	11.4	13.0	198	1.87	2.22
144	10.6	13.0	200	1.76	2.09